Launching Small Satellites in the Former Soviet Union

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Abstract

This paper summarises the experience gained by CST Russian and British staff while brokering and managing the launches of small satellites in the Former Soviet Union (FSU). The seven currently available small launchers are compared for availability, utility and price. Methods of achieving economical access to space such as piggy-back or cluster launches are assessed and guide lines suggested for achieving the best results. CST experiences with all three basic launch solutions in the FSU and the lessons learned are described.

Including contracts currently in hand, by the end of 2005 CST will have brokered and managed the launches of over 20 small satellites of 6 to 400 kg mass to a variety of orbits (including GEO) on at least 5 different FSU launchers. At the moment, none of the satellites will be from the USA. The paper is intended to give some light on some of the reasons why and suggest possibilities for improving the situation.

The recent record of FSU small launchers will be presented and this and important related issues will be discussed. The likely evolution of the FSU launcher situation over the next 10 years will be reviewed and 2 or 3 promising developments will be discussed in detail.

1. Background

Since the collapse of the Former Soviet Union (FSU) much activity on the development of numerous projects concerned with launch vehicles has taken place in Russia and Ukraine. It is now possible to say that the situation in this field has become, while evolution continues, sufficiently clear and stable at the present time. Three directions have characterized activity over the last 10 years, and these were taken by the Russian and Ukrainian launcher manufacturers according to their capabilities and potential, which were mostly inherited from Soviet times.

Firstly, those companies which had operational launch vehicles at their disposal, i.e. which were able to undertake the production and operation of these launchers, were trying to establish their commercial operation simultaneously with undertaking rather rare and badly paid state orders which could not be refused by these companies since they themselves were state owned.

Secondly, those companies, which had at their disposal (in the same sense) ballistic missiles (intercontinental ballistic missiles, ICBMs or submarine-launched ballistic missiles, SLBMs) were trying to convert them into small launch vehicles also intended for commercial operation. Such an aspiration for commercial operation was explained by the circumstance that the FSU (Former Soviet Union) countries could not be considered good customers of launchers for their national programmes due to the difficult economic conditions at that time.

It is necessary to add that, besides Russia and Ukraine, other FSU countries tried to be involved in the potential use of former ICBMs as commercial space launchers. Thus, Kazakhstan had a number of the heavy SS-18s and their launch silos as well as test silos for the SS-18s and SS-19s at Baikonur.

The basis for the hopes to gain money by the commercial using of both small launch vehicles and converted ballistic missiles was, undoubtedly, the forecasted sharp growth of demand in the world's market of launch services for the injection of a huge number of small communication satellites which were planned in the frames of large low-orbital satellite communication system projects, for example, 'Iridium', 'Teledesic', 'Globalstar' etc. When the first of these systems, 'Iridium', was being deployed, the most advanced Russian converted launch vehicle, 'Rockot' was even lucky to capture its share of orders for injections of some of the system's satellites which apparently confirmed the expected opportunities.

However, this also confirmed one more circumstance. The 'Rockot', equipped with an especially developed upper stage (the development of which had been begun in the Soviet times) was found to be suitable for the injections of these modern small communication satellites while other ready converted launch vehicles were not suitable for this task, even the heavy 'Dnepr' (SS-18K at that time) was not suitable without the development of a special upper stage. These other converted small launch vehicles had too low lift capacities to service unmodified the waited boom of small communication satellite injections. The projects for more complicated converted launch vehicles having larger lift capacities, for example, the 'Priboy/Berkut' or even the improved 'Dnepr' required significant investments for their realizations. The bankruptcy of

'Iridium' postponed the waited boom for a number of years and these investments became problematic. At the same time, the ballistic missiles which would be converted into effective small launch vehicles had a time limit, since their production had been halted while their lifetimes approached inexorably to their term of expiration.

This was the beginning of the end for the 'period of FSU converted launchers predominance'. The situation was complicated by the consequences of the START Treaty implementation: Kazakhstan transferred its SS-18s to Russia and destroyed the silos on its territory and has recently confirmed the intention to transfer the test silos at Baikonur to be under the jurisdiction of Russia, while Ukraine, in an accordance with its obligation to have no offensive strategic armaments on its territory after December 5, 2001 (although it had a number of removed but not destroyed ICBMs) has actually abandoned all projects of converted launch vehicles excluding a participation in the current commercial operation of the 'Dnepr'.

A similar situation with converted launch vehicles has arisen in Russia as well. The projects of such launchers were either just realized or shelved. An exception is the 'Strela' project, which is near to realization and will have its first flight soon.

The third direction was the development of quite new advanced projects which had no regard to the conversion of ICBMs/SLBMs.

Initially, almost none of the companies developed new projects for small launchers. However, most of the projects which had been initiated in the Soviet time were abandoned, for example, the 11K55 ('Vzlyot'), the planned successor for the 'Cosmos'. There was only a single exclusion: the 'Energia' Rocket Space Corporation (RSC), the largest Russian space company had no launcher of its own after the cancellation of the 'Energia/Buran' programme and began to develop the 'Quant' project on the basis of its available technologies.

However, a range of new projects arose in connection with opportunities for both concrete foreign orders and the potential for the using of these new launchers for national space programmes (as a replacement of old operational launch vehicles). A few of these projects were led up to the stage of readiness for hardware manufacturing. Unfortunately, only one of them is being realized at the present time ('Angara-1') while the other ones have been shelved like the above mentioned projects for advanced converted launchers since the foreign orders were abandoned while the national space agencies of Russia and Ukraine have not yet sufficient money for a full-scale realization of these projects exclusively for their own purposes.

2. Why FSU Launchers?

Perhaps the first question that should be settled is: why FSU launchers? The following five non-technical points alone are enough to explain the current great interest in FSU launchers, particularly for launching small satellites.

- Even though now considerably reduced from its past Soviet glories, FSU space activity is still vast and multifarious.
- Russian and Ukrainian activity involves a variety and quantity of launches to all the orbits required by small satellites (except, perhaps, equatorial).
- Due to the recently tough financial conditions in the FSU, prices are favourable and companies eager to please and competitive.
- The de-commissioning of a great many missiles has led to a flood of 'conversion' launchers
- A large number of possibilities for piggy-back launches are available and there exists a willingness to adapt major national missions to this end.

3. FSU Launcher Families and Their Technical Advantages

What launchers are we actually talking about? There are now six main classes of launchers in the FSU, four of which are families derived from an original single vehicle (all the larger systems). One of these systems, the super-heavy Energia/Buran, is now defunct but could be revived given the (unlikely) circumstance of sufficient demand and money. The imminent introduction of the 'Angara' system (to replace the Russian Baikonur launched 'Proton' system with one of similar or greater capability that can be launched from Plesetsk) which is modular, like the Energia launcher, will go some way towards replacing its capabilities. The larger launchers have varying potentials for piggy-back rides of small satellites, and thus the ability to compete with smaller launchers and converted missiles. The six classes are:

- Energia/Buran system (now defunct)
- Proton/Proton-M (ultimately, Angara 5)
- Soyuz Family (perhaps, Angara 3)
- Zenit 2 (Ukrainian) Zenit 3 (Sea Launch)
- Small Launchers –Cosmos and Tsyklon (soon, Angara 1)
- Converted Missiles – Shtil, Start, Strela, Rockot, Dnepr

There are many technically advantageous characteristics of FSU launching systems which lead to their greater reliability and economy of use. Many of these characteristics are quite subtle and deserve a paper of their own. Eight of the main ones are:

- System approach to launcher, launch complex and operations design
- Long production runs planned at the outset (and usually achieved). Not preceded by lowest cost

prototype (as in STS, Ariane-5)
- Continuous and large (now mostly past) investment in engine design and development (use of efficient engines lowers the mass-fraction of the launcher)
- No-fuss approach, such as the use of railway transport, introduction of exotic fuels (e.g., cryogenic) only when absolutely necessary
- Standardisation of launchers, which are non mission-specific, which allows rapid turnaround/changes of payload at the cosmodrome
- Very experienced launch crews (at least in the past)
- Some new small launchers are ex-missiles, with military specifications, and even better all weather capabilities than Soyuz or Proton (which were in themselves military designs)
- Convenience and cost savings associated with the universal adoption of horizontal integration and pre-launch testing.

4. Methods of Economically Launching Small Satellites

There are three principle ways of reducing the launch costs of small satellites, dedicated launches on small launchers, launching satellites in clusters on small launchers and launching satellites as ‘piggy-backs’ with larger satellites on dedicated missions using launchers of any size.

4.1. Dedicated Launches

All currently available small launchers and converted missiles, plus two that are almost certainly to be introduced soon, are described below. With the exception of one of these, Angara, all small launchers were derived from missile projects. However, in the case of Tsyklon and Cosmos, the launchers have been developed from missiles from which they are separated by some distance (both in terms of time and modifications) and also were manufactured separately, rather than using decommissioned current missiles, as with the recent spate of missile conversions since 1991.

Thus, FSU small launchers are dealt with in two separate categories, ‘Current Small Launchers’, and ‘Converted Missiles’. For reasons of price, converted missiles are the obvious choice where their mass and orbit capabilities allow. For satellites of under 500 kg, this method is usually uneconomical (except with Start and Shtil) and the other methods should be considered.

4.1.1. Current Small Launchers

The maximum payload capability is given as an approximate figure for a reference orbit of 200 km altitude with an inclination of 65^{o}. The reference price of a launch is based on that quoted by the manufacturers (see Section 5).

‘Cosmos-3M’ Obsolete but reliable and proven design. Sufficiently good ranges of inclinations and sufficiently high payload masses. However, the available number of launchers would provide a commercial operation only for a few more years. Maximum payload capability is 1.4 tonnes, price of launch is under US$ 10 mln. See Figures 1&2.

‘Tsyklon’ Reliable and proven design. Only a very few remaining launchers are available at present. Serial production is halted but the assembly of single launchers is being continued. There is some potential for the renewal of serial production and some projects, such as its use from Alcantara, Brazil are still being discussed. Maximum payload capability is about 3.5 tonnes, reference price of launch is estimated as US$ 15-20 mln. See Figure 3.

‘Angara-1.1/1.2’ Advanced new design but using well proven technology, offering a broad range of services including, probably, a range of launch azimuths. However, will be put into operation only after 2-3 years (but with a high probability). Maximum payload capability should be 2.0/3.7 tonnes, reference price of launch would be at the level of US$ 20 mln. See Figure 4. A large range of heavier launchers will be built up from the basic Universal Rocket Module (URM) used and qualified in this launcher.

4.1.2. Converted Missiles

The category of converted missiles can be somewhat confusing until one realises that, as with FSU launchers in general, these are also in families, each derived from a current or recent missile system. The SS-24, from which several quite attractive launching systems have been designed (such as ‘Space Clipper’), is unlikely to produce a family as have the other missiles because of the strict arms limitation controls and other circumstances placed on it. However, it is added to the list of four missile types from which families of launchers are being derived, below, for completeness.
- SS-25 Family: Start, Start-1: Manufactured by MIT. Commercial company is Complex. Transportable launch base could be used outside Russia (politics depending). Small capacity, good launcher with a potential future.
- SS-19 Family: Strela, Rockot, Rockot K, Eurockot: Manufactured by Khrunichev. Commercial companies NPO-M and Eurockot respectively. Dependant on stock but plenty at present.

Fig. 1. Launch of Cosmos no 400 from the Plesetsk Cosmodrome on 28th June 2000 carrying the satellite NADEZHDA (Russian MoD) and 2 ‘piggy-backs’: ‘Tsinghua-1’ (built by SSTL for Tsinghua University) and SNAP-1 (SSTL). Both ‘piggy-back’ launches were brokered and managed by CST for SSTL. Photo CST

Fig. 2. Left: CST, SSTL, Rosoboronexport, and Polyot personnel together on the occasion of the signing of the launch agreement for the SSTL Disaster Monitoring Constellation (DMC) at the Farnborough Air Show in July 2002: - 7 satellites in total on 3 Cosmos launches Photo Rosoboronexport;
Right: The first satellite in the series, Alsat, is to be launched on 28th November 2002. Photo: - Fit check at Polyot, September 2002 Photo CST

Fig. 3. Left: A continuation of the 'Tsyklon's' launches is connected with how existing stocks are used. Yuzhnoye;
Right: The pedigree and versions of the 'Tsyklon' launch vehicle: 1 - R-36 (SS-9) ICBM; 2 - Fractional Orbital Bombardment System (FOBS); 3 - Tsyklon-2' two-staged launch vehicle intended for injections of nuclear-powered RORSAT (US-A) satellites; 4, 5 - 'Tsyklon-2' for injections of EORSAT (US-P/US-PM) satellites; 6 - 'Tsyklon-2' for injections of ASAT (IS) satellites; 7 - 'Tsyklon-3' three-staged launch vehicle. Yuzhnoye

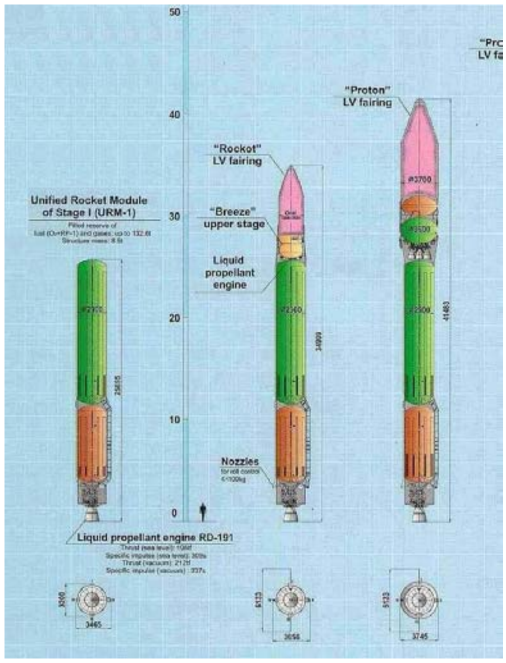


Fig. 4. Left: The body of the 'Angara-1.1's' first stage together with 'old' (behind) and new composite (in front plane) fairings in the work-shop of the Khrunichev's Plant.
Right: Designs of the URM, 'Angara-1.1' and 'Angara-1.2' (left to right). Khrunichev

- SS-18 Family: Dnepr (basic version + various options including US upper stages and versions using SS-24 technology): Manufactured by Yuzhnoe Design Bureau (Ukraine). Commercial company is Kosmotras.
- Navy Missile Family: Shtil, Berkut, Troika (Riksha, Unity). Projects led by Makeev. Determined and viable company with interesting technology. No great success yet. CST is working on launch solutions involving this family.
- SS-24. A highly advanced solid propellant missile combining mobility with near Rockot performance. Would make a very suitable small launcher family but highly controlled and likely to be destroyed.

The converted missiles are now very briefly described. Where greater technical description is required, user's manuals are available for the operational launchers. Reference orbit as before, 200 km, 65°.

'Dnepr' Has now been put into commercial operation and has a good lift capacity comparable with 'Cosmos' and 'Rockot' with a low launch price. Limited range of inclinations, but will be able to go to SSO from the CST brokered Demeter Launch in 2004. Confirmed capability of micro/mini-satellites 'cluster' launches. Maximum payload capability is higher than 3 tonnes (could be enhanced up to 4.4 tonnes), launch price with a complete payload would be near US$ 10 mln in unmodified form, but will be higher if upper stages are used. See Figure 5.

'Rockot' Is now in commercial operation. A broad range of injection services. A capacity for constellation deployment. The launcher is also offered in a package with the 'Yacht' space bus. Maximum payload capability is 1.9 tonnes, price of launch is US$ 12-15 mln. See Figure 6.

'Strela' High probability to be put into operation soon. Potentially relatively low prices, but narrow ranges of orbit altitudes and rather low lift capacity. Besides, it probably will be used mostly for the developer's dedicated missions. Maximum payload capability would be at the level of 1.4 - 1.5 tonnes, reference launch price would not exceed US$ 10 mln. See Figure 7.

'Start-1'/'Start' In operation. Broad range of orbit inclinations but low lift capacity. Can be launched from foreign territories. Maximum payload capability is approximately 0.6/0.9 tonnes, reference price of launch is US$ 8 mln. See Figure 8.

'Shtil'/'Volna' Only for micro payloads. Terms of launches are in strong dependence on the navigation plans of the Russian Navy and a range of inclinations is limited. Very low launch prices. However, Shtil-2 which may come into operation in 2-3 years offers dedicated launchers of minisats up to 250 kg at piggy-back prices. Maximum payload capabilities are at present 160 kg with very restricted payload volume for the 'Shtil', and a few tens of kilograms for the 'Volna'. Current launch prices are around US$ 1-2 mln while a 'Shtil-2' dedicated launch would have a price of up to US$ 4-5 mln. See Figures 9 and 10.

4.1.3. Future Developments for Converted Missiles

The future viability of converted missiles will depend on several factors:

1. The numbers of the remaining stocks of those missiles no longer being manufactured.
2. The state of the remaining stocks of missiles and other relevant items, particularly with regard to their serviceable lifetimes.
3. Present and future competition from other launchers.
4. Political agreements.

For the SS-18 and SS-19 derived launchers (Dnepr, Rockot and Strela), at the current rate of use, factor 2 is likely to predominate over factor 1 in assessing the time when they cease use.
Until recently, the Start treaty placed a limit (absolute in the case of Dnepr) at 2007, but since 2002, when the United States declined to ratify it, this treaty has lapsed. However, the 'extra life' gained as a consequence by the SS-18s and 19s will only be about 5 years, i.e. to about 2012 until age and decrepitude begin to make the entire stock of missiles uneconomic to use. (Kosmotras has said that the SS-18 could be 're-lifed' to 2020.)

The converted launchers that will undoubtedly benefit from this demise will be Start and Shtil whose basic missile components are still in manufacture and therefore are still viable until at least 2020. Both also have another potential survival characteristic: their smallness and cheapness.

While the SS-18 and 19 missile conversions will soon face competition from new especially designed commercial launchers such as Angara 1, they are cheap enough to survive and even compete with Start and Shtil. However, after 2012 these very light launchers will fulfil a niche that the custom-built launchers will be unable to service at the same price, i.e. the one of dedicated launchers for satellites of up to a few hundred kilograms mass, and will therefore come into their own.

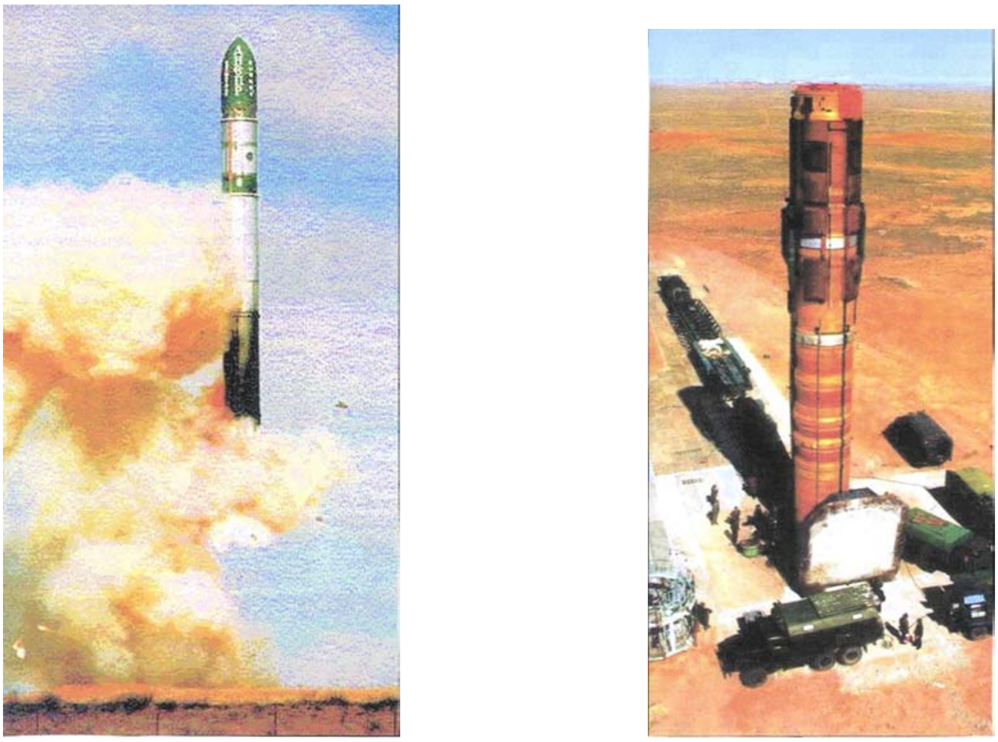


Fig. 5. The ‘Dnepr’ LV. Left: The demonstration launch of the ‘Dnepr’ LV with the British UoSat-12 satellite built by SSTL, 21.04.99. Launch arranged by CST. KOSMOTRAS
Right: An SS-18, which will be used as the ‘Dnepr’ launch vehicle for commercial launchers of small satellites, being installed into a silo. ROSAVIACOSMOS

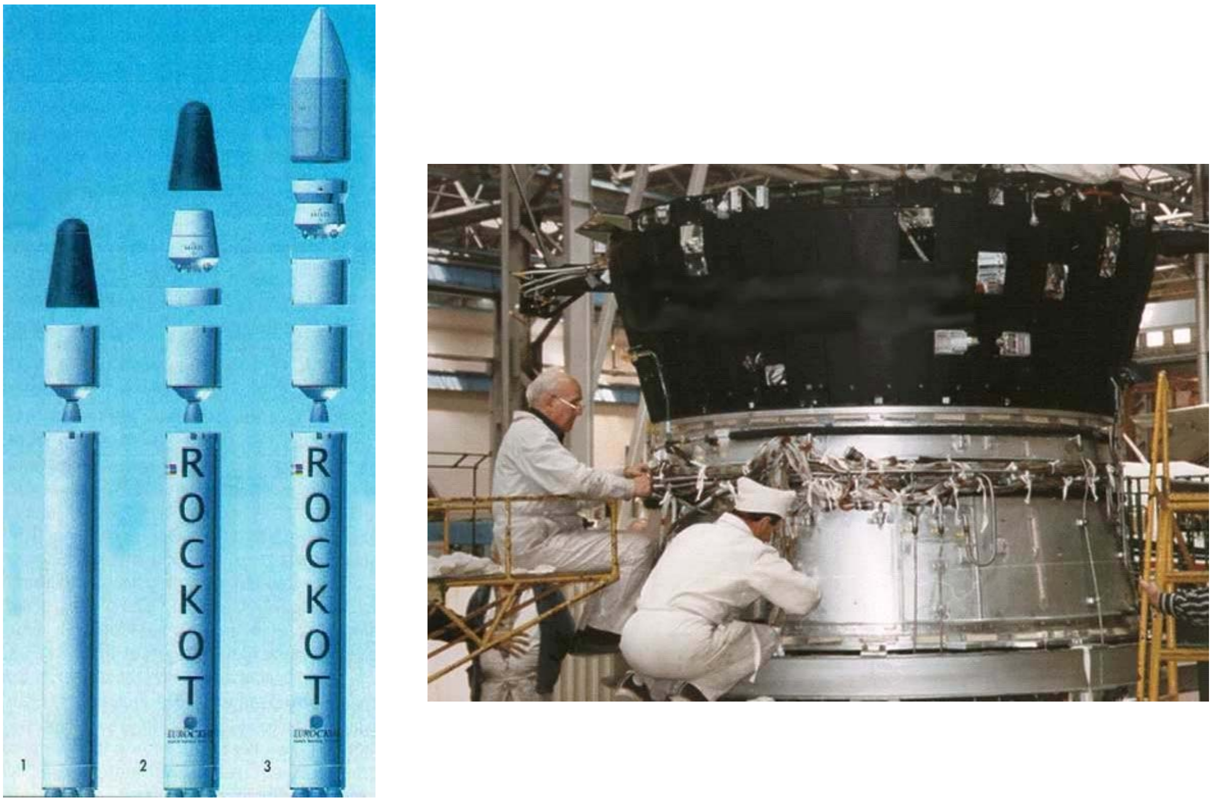


Fig. 6. Left: The pedigree and versions of the ‘Rockot’ launch vehicle: 1 – SS-19 ICBM; 2 – initial version of ‘Rockot’ with ‘Breeze-K’ and ‘old’ fairing; 3 – current ‘Rockot’ with ‘Breeze-KM’ and new composite fairing;
Right: Assembling the ‘Breeze-KM’ upper stage, the improved version of ‘Breeze-K’, for the first flight example of the commercial ‘Rockot’ Khrunichev

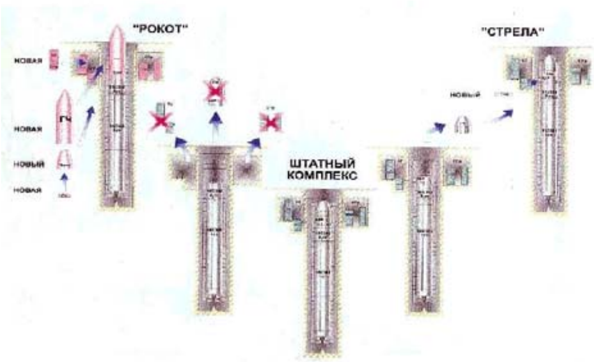


Fig. 7. Top: The evolution of the 'Rockot' and 'Strela'' from the SS-19;
Bottom: Beginning of work on the former SS-11 silo for the 'Strela' launchers at Svobodny NPO Mashinostroyenia

Basic characteristics	
Range, km	intercontinental
Launch weight, t	45.1
Warhead	monoblock, nuclear
Payload, kg	1,000
RV nuclear charge yield, Mt	0.55
Accuracy (maximum deviation), km	0.9

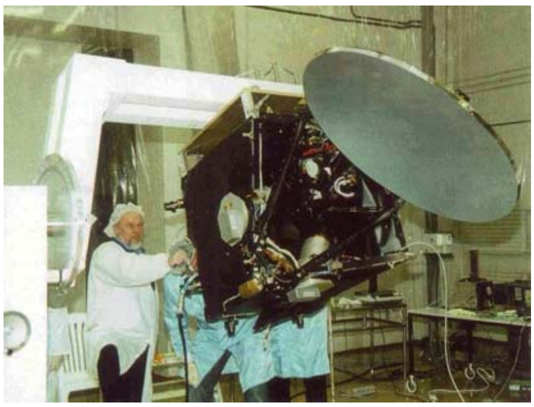


Fig. 8. Left: The 'Topol' road-transportable ICBM Military Publication
Right: The Swedish 'Odin' satellite injected by the 'Start-1' Novosti Kosmonavtiki

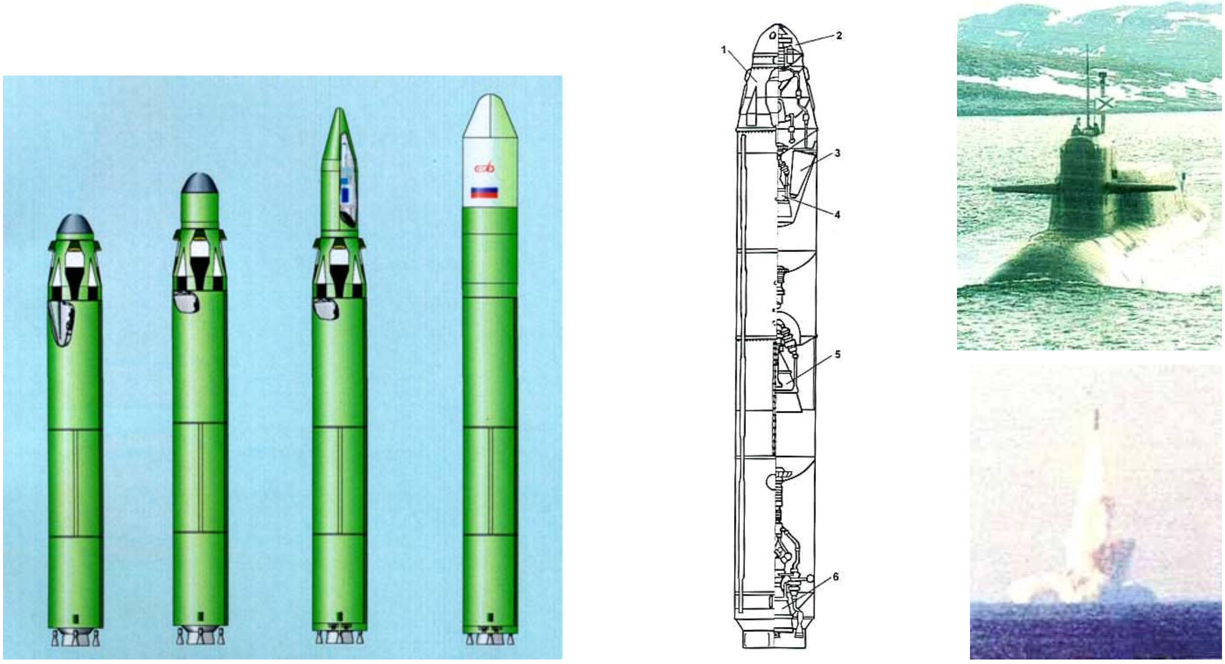


Fig. 9. Left: The ‘Shtil’ family of launch vehicles converted from the SS-N-23 (RSM-54) SLBM, from left to right: ‘Shtil-1’, ‘Shtil-2.1’, ‘Shtil-2’, ‘Shtil-3’
Right: German customers used the ‘Shtil-1’ (SS-N-23) (left) for the orbital launch of ‘Tubsat’ satellites from the ‘Novomoskovsk’ nuclear submarine (right). 1 - head unit; 2 - instrumental compartment; 3 - warheads or payloads; 4,5,6 - main rocket engines of stages SRC Makeyev

Fig. 10. Left: The ‘Volna’ launch vehicle converted from the SS-N-20 (RSM-50) SLBM;
Right: Loading the ‘Volna’ into a submarine before the launch of the ‘Cosmos-1’ spacecraft SRC Makeyev

Thus, provided that factor 4 does not come into play for some reason not yet apparent, the future for missile conversions, whatever the total market demand may be, contains a definite bridge-point in about 10 years time.

4.1.4. Political Restrictions on Small Launchers

(Notes on problems concerned with the danger of the potential use for terrorist actions of certain launch systems.)

A number of the START Treaty's articles as well as the Missile Technology Control Regime are directed to an elimination of the danger concerned with the falling of strategic offensive armaments, primarily ballistic missiles or the technologies for their creation, into the hands of so called 'rogue-countries' i.e. countries, the governments of which are adhering to a policy grounded-on or allowing terrorist actions against other countries. The United States are especially vigorous in pursuing the exact implementation of these articles, sometimes even exceeding reasonable limits. However, the terrible events of September 11, 2001 have shown that these apprehensions were not groundless. Moreover, it has become evident that the executors of such large-scale terrorist actions could be secret international terrorist organizations having more capacities, both financial and technical, than some separate 'rogue-countries'.

In a view of the recent events it is reasonable to examine even in a preliminary fashion, the danger which could be created by the use of small launch vehicles as tools for terrorist attacks.

Indeed, all the small launch vehicles are nearer to ballistic missiles than the launch vehicles of other classes thanks to their dimensions and masses and the times of pre-launch preparation. Moreover, a number of them are solid-propellant ones or are using storable propellants, which enhances even more their readiness for launch (not without a reason, since they were converted from military ballistic missiles). Thanks to these features, really, a certain number of current small launch vehicles could be used as the means for the deliveries of warheads to targets with a quick change of the control system's software during a short period after a potential seizure of a launch site by groups of terrorists.

Such seizures are more possible for mobile launch vehicles, which would be located at temporary launch sites or intermediate airfields (for air-launch systems), situated in the territories of Third World's countries. Indeed, it is difficult to imagine that terrorist groups could capture the launch sites at the well-guarded spaceports of the United States or, especially, Russia where even the routine servicing of launchers is being provided by the militaries. However, these seizures would be more simply realized at the territories of such countries as Brazil, SAR and, probably, even Australia, especially in regard to launch vehicles which are not under the jurisdiction of the START Treaty (special measures were foreseen for converted ICBMs/SLBMs, especially mobile ICBMs, for their safeguarding during operation at the territories of foreign countries).

It can be supposed that such a seizure is possible. However, there are significant problems which prevent the use of any small launch vehicle for a terrorist attack against a target. First of all, calculations and a change of software should be necessary as well as a completion of the pre-launch preparation. The methods and technologies for operation would be available for terrorists only in the cases when a launch vehicle of the non-converted type was developed or delivered especially for an operation from the country of a customer (such as the 'Unity' project). The according documentation would be received in an illegal way in the customer country, which might have insufficient experience for safeguarding this documentation. A compulsion of the servicing personnel to carry out necessary operations would have to be made by the terrorists as well. (This would take place in regard of the carrier aircraft's crew in the case of air-launched systems). Moreover, there would be an alternative between life and death in the case of meeting the terrorists' requirements (instead of an unavoidable death in the method which was used by the terrorists on September 11, 2001 in regard to the captured airplanes' crews).

The next problem is a more serious one for terrorists. The head units of small launch vehicles (i.e. the units, which consist of the payload, its fairing and, in some cases, upper stages) could not be considered any substitute for a warhead: firstly, nose fairings are not designed for entering into dense layers of atmosphere with high velocities. Hence, even in the case of the command for the ejection of the fairing being eliminated, the head unit will still be destroyed before the hit of the target. Secondly, even modern ICBMs and SLBMs cannot provide an accuracy of such a hit of less than a hundred meters without the using of additional targeting by the warhead's special homing systems.

Hence, terrorists should have to have a warhead which should be installed onto a captured launch vehicle and this warhead should be compatible with the launcher's payload adapter and the system for payload separation.

It is difficult, but possible nevertheless, to imagine the development and manufacturing of such a warhead on the basis of the launcher's documentation received in either legal (as a potential customer) or illegal ways. However, it is quite difficult to imagine an effective use of this warhead without a significant volume of preceding testing in real flights. This is an uncertain enterprise, in comparison with which even an attempt to seize a real ICBM can be considered as having more chances for success.

Nevertheless, attempts at even the most unbelievably shady enterprises can be found in the newest history. Hence, the examined danger should not be neglected altogether. Rather, it merits a special study. At the present time, it is possible to note two preliminary statements: firstly, the small launchers which are most suitable to be used for terrorist purposes are those which are launched from the territories of foreign countries, especially countries of Third World, and, secondly, non-converted launchers are the most probable candidates to be used for these purposes since their documentation is more available than for converted ones.

4.1.5. Tables of Recent and Future Launches of FSU Small Launch Vehicles

Table 1
RECENT LAUNCHES

No.	Date	Launch vehicle	Space-port	Orbit		Payload *(Country)*	Mass of payload in orbit	Purpose	Notes
				Height, *km*	Inclina-tion, *deg.*				
1999									
1	21.04.99	***Dnepr***	Baikonur	Circ. 660	64.5	UoSAT-12 *(UK)*	325	Test	Brokered by CST
2	28.04.99	***Cosmos***	Kapustin Yar	550×559	48.5	ABRIXAS *(Germany)*	550	Scientific	-
				548×605	48.5	Megsat-O *(Italy)*	35	Experimental (communication)	
3	26.08.99	***Cosmos***	Plesetsk	984×1021	82.9	Cosmos-2366 /Parus/ *(Russia)*	800	Military navigation/ communication	-
4	26.12.99	***Tsyklon-2***	Baikonur	415×428	65.0	Cosmos-2367 /EORSAT/ *(Russia)*	3150	Ocean reconnaissance	-
2000									
1	16.05.00	***Rockot***	Plesetsk	538×559	86.4	SIMSAT-1 *(Russia)*	657	Demonstration	Payloads were mass/dimensional mock-ups of ‘Iridium’ satellites
				540×553	86.4	SIMSAT-2 *(Russia)*	660	Demonstration	
2	28.06.00	***Cosmos***	Plesetsk	685×727	98.12	Nadezhda *(Russia)*	800	Rescue (COSPAS-9)	Chinese and UK satellite launches brokered by CST
				686×728	98.12	TSINGHUA-1 *(China)*	49	ERS	
				685×725	98.13	SNAP-1 *(UK)*	8.3	Test	
3	15.07.00	***Cosmos***	Plesetsk	424×485	87.27	MITA *(Italy)*	169.9	Test/scientific	Non-separable ‘Bird-Rubin’ was installed in second stage as well
				429×485	87.27	CHAMP *(Germany)*	522.2	Scientific	
4	26.09.00	***Dnepr***	Baikonur	644×670	64.56	TIUNGSAT-1 *(Malaysia)*	54	ERS	Management by CST
				642×667	64.56	MEGSAT-1 *(Italy)*	54	Communication	
				644×688	64.56	UNISAT *(Italy)*	10	Scientific	
				643×680	64.56	SaudiSat-1A /SO-41/ *(Saud. Arab.)*	10	Test/ communication	
				644×683	64.56	SaudiSat-1B /SO-42/ *(Saud. Arab.)*	10	Test/ communication	
5	20.11.00	***Cosmos***	Plesetsk	-	-	Quick Bird-1 *(USA)*	981	ERS	Failure of launcher due to premature shut-down of 2^{nd} stage engine
6	05.12.00	***Start-1***	Svobodny	496×534	97.32	EROS A1 *(Israel)*	250	ERS	-

7	27.12.00	***Tsyklon-3***	Plesetsk	-	-	Gonets D1 Gonets D1 Gonets D1 Strela 3 Strela 3 Strela 3 *(Russia)*	230 230 230 230 230 230	Communication Communication Communication Military comm. Military comm. Military comm.	Failure of launcher due to emergency shut-down of 3rd stage engine
2001									
1	20.02.01	***Start-1***	Svobodny	615×650	97.8	Odin *(Sweden)*	250	Scientific	-
2	08.06.01	***Cosmos***	Plesetsk	981×1023	82.9	Cosmos-2378 *(Russia)*	800	Military navigation/ communication	-
3	20.07.01	***Volna***	Barents Sea (from submarine)	-	-	Cosmos-1 *(USA)*	40	Experimental	Failure. Satellite did not separate from launcher
4	31.07.01	***Tsyklon-3***	Plesetsk	501×549	82.5	Koronas-F *(Russia/Ukraine)*	2260	Scientific	-
5	21.12.01	***Tsyklon-2***	Baikonur	412×421	65	Cosmos-2383 /EORSAT/ *(Russia)*	3150	Ocean reconnaissance	-
6	28.12.01	***Tsyklon-3***	Plesetsk	1421×1448 1420×1447 1419×1447 1418×1447 1415×1447 1408×1445	82.5 82.5 82.5 82.5 82.5 82.5	Cosmos-2384 Cosmos-2384 Cosmos-2384 Gonets-D1 No. 10 Gonets-D1 No. 11 Gonets-D1 No. 12 *(Russia)*	? ? ? 230 230 230	Military comm. Military comm. Military comm. Communication Communication Communication	-
2002									
1	17.03.02	***Rockot***	Plesetsk	496×521 496×522	89.0 89.0	GRACE-1 GRACE-1 *(USA/Germ.)*	496 496	Scientific Scientific	-
2	28.05.02	***Cosmos***	Plesetsk	970×1029	82.96	Cosmos-2389 *(Russia)*	800	Military navigation/ communication	-
3	20.06.02	***Rockot***	Plesetsk	Circ. 650 Circ. 650	86.35 86.35	Iridium-97 Iridium-98 *(USA)*	683 686	Communication Communication	-
4	8.07.02	***Cosmos***	Plesetsk	1480x1526 1481x1517	82.21 82.42	Cosmos-2390 *(Russia)* Cosmos-2390 *(Russia)*	200 200	Military communication	-
5	12.07.02	***Volna***	Barents Sea	Sub-orbital		Demonstrator-2 *(Russia/Germany)*	146	Experimental	Failure. Spacecraft was not found
6	26.09.02	***Cosmos***	Plesetsk	984x1030	82.9	Nadezhda-M	800	COSPAS-SARSAT	-
7	28.10.02	***Cosmos***	Plesetsk	691x772 694x774	98.24 98.24	Mozhaets AlSat-1	69 90	Educational DMC	Alsat launch brokered by CST
8	20.12.02	***Dnepr***	Baikonur	638x688 638x687 636x709 640x678 635x720 641x668	64.56 64.56 64.56 64.56 64.56 64.56	Rubin-2 *(Germany)* UNISAT-2 *(Italy)* SaudiSat-1C *(Saud. Arab.)* *LatinSat-A* *LatinSat-B* *(USA)* Dummy of TrailBlaser *(USA)*	30 10 15 10 10 420	Test/comm.. Scientific Test/comm.. Test/comm.. Test/comm..	
2003									
1	4.06.03	***Cosmos***	Plesetsk	1000	83	Military SC	-	-	(TBD)

Table 2
KNOWN PLANNED LAUNCHES FOR 2003-2005

No.	Launch vehicle	Spacecraft *(Country)*	Sort of orbit	Purpose	Planned term of launch	Note
1	***Rockot***	MOST *(Canada)* MIMOSA *(Czech)* *CubeSat XI-IV (Japan)* *CUTE-I (Japan)* *CanX-1 (Canada)* *AAU CubeSat (Denmark)* *DTUSat (Denmark)* *QuakeSat (USA)*	LEO LEO 650 km SSO	Scientific Experimental Scientific	June 2003	
2	***Cosmos***	BILSAT (~100 kg) (Turkey) Nigeriasat (~90 kg) (Nigeria) UK DMC (~90 kg) (UK) KaistSat – 4 (S. Korea)	LEO (686 km SSO)	Disaster monitoring ERS	III - 2003	DMC 2nd launch managed by CST
3	***Strela***	-	-	-	III - 2003	From Baikonur
4	***Strela***	-	-	-	Late 2003	From Svobodny
5	***Tsyklon-3***	Sich-1M (Ukraine)	LEO	Disaster monitoring	III - 2003	
6	***Tsyklon-2***	Cosmos	-	-	Late 2003	
7	***Rockot***	Monitor-E *(Russia)*	LEO	ERS	Late 2003	
8	***Volna***	Cosmos-1 *(USA)*	LEO	Experimental	Late 2003	
9	***Rockot***	Service - 1	SSO	Communication	September – October - 2003	Foreseen realization of option
10	***Shtil***	KybSat (Germany)	-	Scientific	2003	
11	***Shtil***	Compas-2 *(Russia)*	LEO	Scientific	Late 2003	Launches will be carried out if 'Compas' concept confirmed
12	***Shtil***	Compas-3 *(Russia)*	LEO	Scientific	Early 2004	
13	***Dnepr***	Demeter (French)	SSO - 700	Scientific	April 2004	CNES satellite, being managed by CST
14	***Dnepr***	*TrailBlazer (USA)*	Moon orbit	Scientific	2004	
15	***Start-1***	EROS-B1 *(Israel)*	LEO	ERS	2004	-
16	***Cosmos***	TOPSAT (~125 kg) *(UK)* Chinasat (120-140 kg) (China) VNSAT (120-140 kg) (Vietnam)	LEO (686 km SSO)	Disaster monitoring	End 2004	DMC 3rd launch being managed by CST
17	***Rockot***	KOMPSat-2 (South Korea)	685 SSO	ERS	Late 2004	
18	***Rockot***	CryoSat (French)		Scientific	2004	
19	***Start-1***	EROS-3 *(Israel)*	LEO	ERS	2005	-

4.2. Cluster Launching and Piggy-Backing

The space launch vehicles of the former Soviet Union were used, on occasion, for, piggy-back payload injections. This kind of insertion into orbit is best for so called nano- and micro-satellites having masses of kilograms and tens of kilograms. Indeed, it would be too expensive to use especially ordered launchers, even of the super-small class such as the American 'Pegasus' or Russian 'Start', for such missions. Examples of such missions can be found only among the test flights of the new launchers or launches of national satellites by launch vehicles from the same nations. Nowadays, such kind of service as the assembling of a 'cluster' of a sufficient number of micro-satellites in order to provide a commercially profitable multiple injection of them with a single launcher is just being offered (e.g., through CST) and has been just twice implemented for the 'Dnepr' launcher, for example.

Nevertheless, a lot of launches are carried out with incomplete loading i.e. the launchers in these missions have reserves of lift capacity which could be used for the gaining of additional money (important for FSU organisations) through the injections of piggy-back payloads. Hence, any launch vehicle, even of heavy class, which is fulfilling a mission of such an injection, can be considered as a vehicle implementing the function of a small launcher with regard to this payload. Hence 'Zenit', when on Russian national missions, is a popular 'piggy-back' carrier.

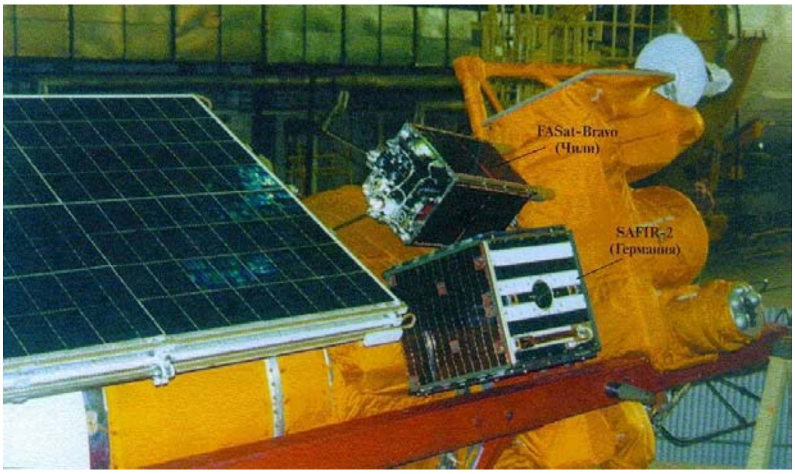
However, a detailed examination of Soviet/FSU experience in this field leads to a surprising result. Despite the fact that this experience has a history beginning from 1972, when the French SRET-1 was injected by the 'Molniya' launcher, up to the present, until recently no piggy-back payloads were separated directly from the top (upper) stage of the launch vehicle! All of them were attached to and separated from the various satellites which were the primary payloads in the concerned missions. Hence, one should talk about piggy-back payloads from spacecraft rather than launchers. A logistical complication, which CST has overcome for its customers, is that such a piggy-back mission is usually arranged with the main satellite manufacturer, rather than the launcher organisation. Examples of this arrangement are the first two CST launches given in Table 3. The Zenit launcher, with Fasat Alpha and TMSat is shown in Figure 11.

The heavier 'Sojuz'/'Molniya' and 'Tsyklon' were never considered for the direct injection of piggy-back payloads and, apparently, it would be hard to arrange for this purpose since they have no free volumes between their top/upper stages and installed adapters with the main payloads. The same might be said about the 'Proton' and 'Zenit-3' launch vehicles equipped with versions of the 'Block-DM' upper stage. However the 'Block-DM', thanks to its large size, has suitable places on its structure and adaptor and CST now has the authority to arrange the direct injection into GEO of piggy-back payloads of up to 400 kg, e.g. GEMINI, see Figure 12.

The 'Rockot', being equipped with the 'Breeze-KM' upper stage, has an opportunity to provide the injections of multiple piggy-back payloads in accordance with the 'Launch a Piggy' Programme which was announced by the 'Eurockot' company in October, 2000. It was reported that the standard dispenser of the 'Breeze-KM' upper stage would accommodate from 2 to 7 piggy-back micro/mini-satellites of masses from 50 to 250 kg. The price of the piggy-back injection per kilo would be US$ 10-15 thousand, as it was announced. Thanks to the relatively high power potential of the 'Breeze-KM', these piggy-back payloads would be delivered into an orbit, the height of which could differ from the orbit of the prime payload. However, all the piggy-back payloads should be separated simultaneously. Every piggy-back satellite should be installed onto a special spacer of 300x300 mm size and should be fastened at four points. No electrical interfaces are provided by the dispenser.

The first launch in the 'Launch a Piggy' (LAP-1) is scheduled for 2003 when the 'Monitor-E' Russian satellite should be injected as a prime payload together with the MOST and MIMOSA piggy-backs. The prime satellite should be injected into a sun-synchronous orbit with heights 550-700 km. However, further customers for this sort of launch service have not been found yet, and therefore the 'Launch a Piggy' programme is now in some doubt. Assembling diverse payloads into a single cluster bunch is not a simple task and this concept was offered by Eurockot as a competition ploy to Kosmotras, the marketers of Dnepr, without realising that they had also run into some serious problems with the concept. Since the Dnepr is fundamentally cheaper than Eurockot (without an elaborate upper stage similar to the Breeze-KM) this ploy may backfire. A Dnepr cluster launch is shown in Figure 13. Kosmotras is more likely to make the cluster concept work and now appears to have succeeded.

Since the 'Breeze-KM' and 'Breeze-M' upper stage have very near designs, apparently, piggy-back payloads could be injected also by the heavy 'Proton-M' and 'Angara' with the 'Breeze-M'. This upper stage will apparently have an additional opportunity to install piggy-back payloads on the ejected propellant tank (they would be separated together with this tank, followed by their own separation). CST's arrangements for GEMINI also cover Breeze-M.



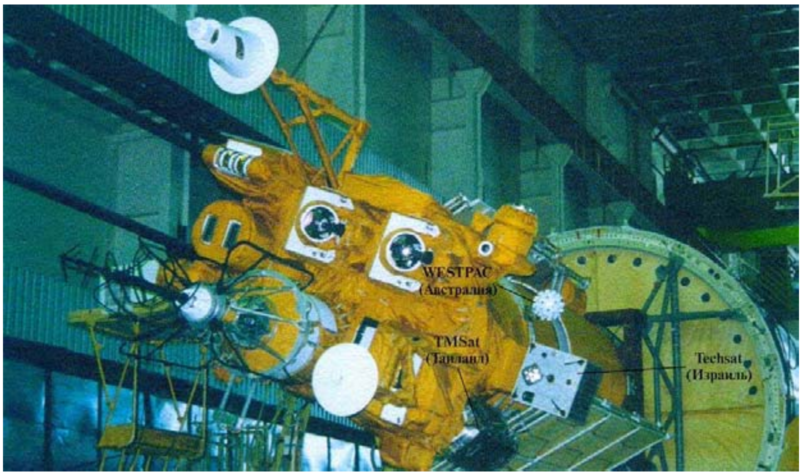
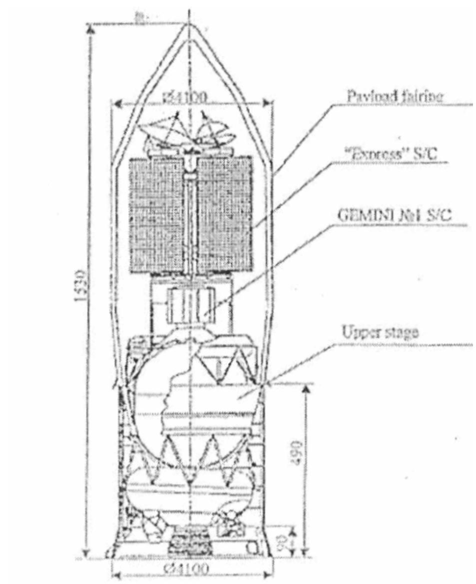
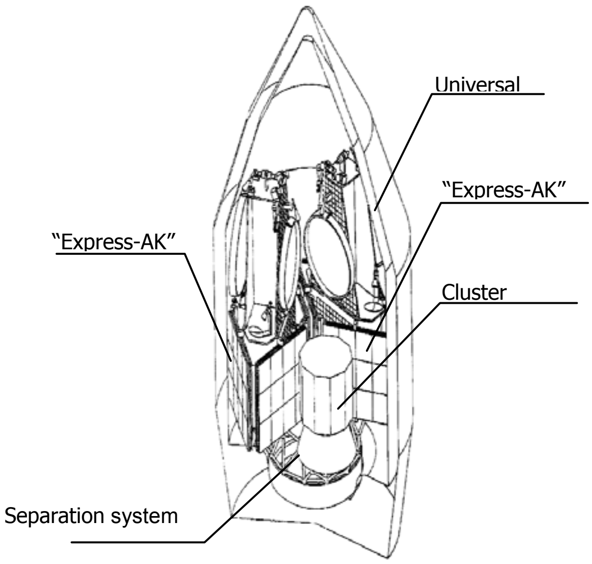


Fig. 11. Top: The installation of the ‘FASat-Bravo’ and SAFIR-2 satellites on the ‘Resurse-01’ satellite.
Bottom: The installation of the WESTPAC, ‘TM-Sat’ and ‘Techsat’ satellites on the ‘Resurse-01’ satellite.



Upper unit with SC and upper stage arrangement



“Packed” arrangement of S/C inside upper unit

Fig. 12. Left: Piggy-Back to GEO - CST is making arrangements with Rosaviakosmos for the launch of small satellites direct to GEO by piggy-backing on a Russian national satellite launch on Proton. Arrangements can be made for other satellites of up to 400 kg very economically (~ 20K US dollars/kg); Right: Cluster to GEO - Cluster launches can also be arranged for GEO small satellites above 400 kg, up to about 800 kg. Above this mass, occasional opportunities arise in the form of specially arranged ‘test’ launches on behalf of federal bodies.

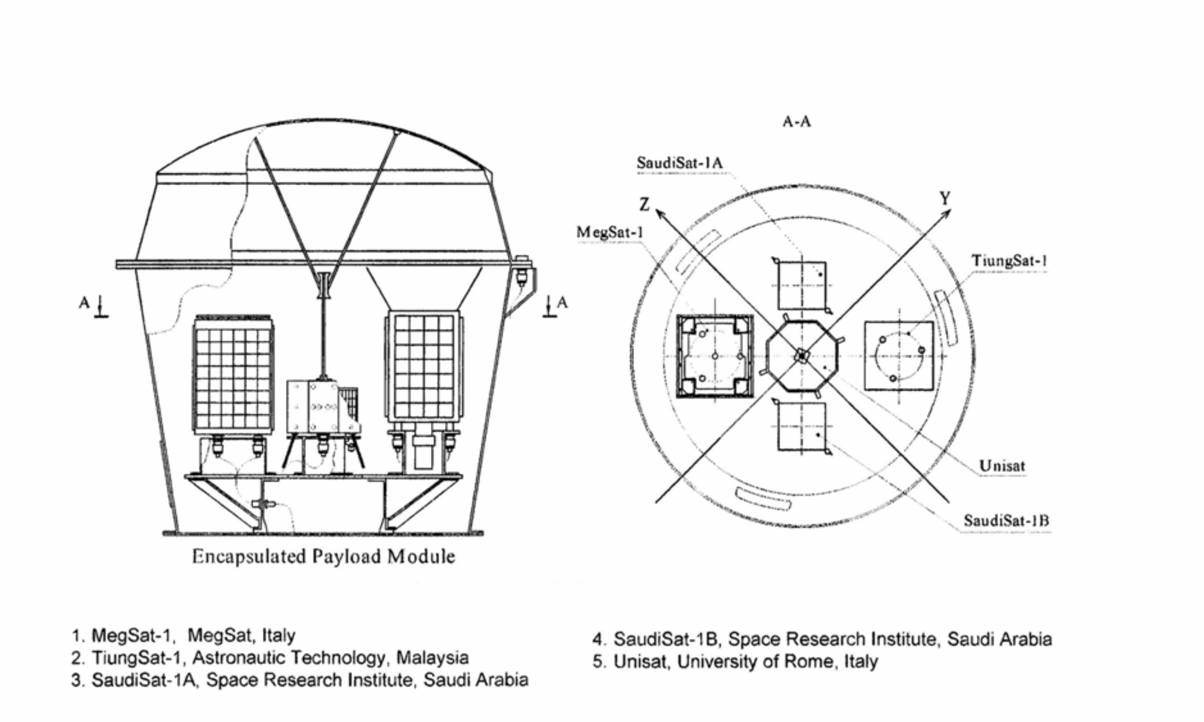


Fig. 13. Dnepr cluster launch KOSMOTRAS

Meanwhile both Cosmos (recently) and Dnepr (soon) can now perform sun-synchronous injections. The first Cosmos to SSO was with SSTL-built Tsinghua-1 (+SNAP) and the first SSO flight of Dnepr will be with CNES-built Demeter, both satellites being under CST launcher brokerage services. Figure 14 shows the mounting structure and preparation for the launch of Tsinghua-1 and SNAP-1.

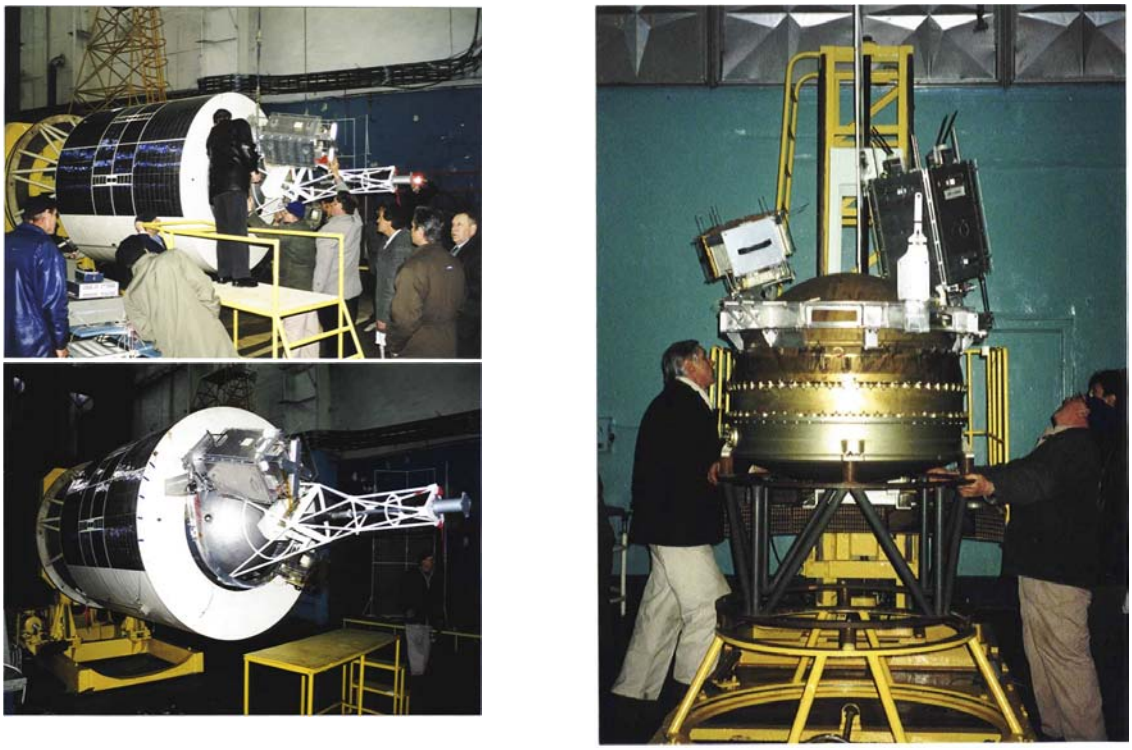


Fig. 14. Fit-check for Tsinghua-1 and SNAP-1, May 2000 with NADEZHDA satellite, showing mounting structure (equivalent to ASAP).

5. Practical Questions

CST Experience

Of CST's specialisations, the one relevant to this paper is FSU launcher services brokering. Table 3 summarises CST's experience in this field.

Pricing

The most important competitors for the small FSU launchers listed in Section 4 are actually other FSU launchers. While such competition exists (and it always will, in some form or other) it is possible to broker in a straightforward way 'across the board' for both 'piggy-back' and dedicated launch services, achieving the best achievable prices and conditions. CST usually manages to achieve further savings by local management on the spot and the conducting of progress meetings and handling bureaucratic processes for clients, which can save a great deal of time as well as money for users of FSU launch services. The most important stage in which extra savings can be achieved is in the construction of the launch services contract and this stage includes CST's interpretation and translation skills as well as its understanding of Russian approach, which is also vital. A close examination of all aspects of FSU space industry and technology should also enable potential customers to assess the technologies, stocks, associations, current situation and ability to do business of the organisations that they wish to deal with.

Table 3
HISTORY OF CST LAUNCH ARRANGEMENTS

Completed			
1995	August 31	Tsyklon (1 piggy-back)	Fasat Alpha
1998	July10	Zenit (2 piggy-back)	Fasat Bravo + TM sat
1999	April 21	Dnepr (1 dedicated)	Uo Sat 12
2000	June 28	Cosmos (2 piggy-back payloads)	Tsinghua 1+Snap
2000	September 26	Dnepr (1 piggy-back payload)	Tiung Sat
2002	November 28	Cosmos (1 piggy-back)	Alsat/DMC-1
Future Schedule			
2003	September	Cosmos (3 in cluster)	NigeriaSat-1, BilSat-1 and UK-DMC/DMC-2
2004	April	Dnepr (main in cluster)	Demeter
	July	Cosmos (2 in cluster)	TopSat+ChinaSat/DMC-3
2005	First half	Proton (1 piggy-back)	Gemini-1
			Other satellites
2006			Others either scheduled or in negotiation

By a combination of all of the price saving methods discussed above, CST has always managed to achieve significant (sometimes dramatic) overall reductions on basic launch price quotations. CST's key to success depends mainly on a well integrated, trusted and specialised team of Russian employees to handle negotiations plus an expert technical team to handle questions as they arise during the working process.

Problems

Linguistic difficulties are actually less important than those with cultural perceptions. Since the organisations involved have only been exposed to Western business methods and culture for a relatively short time, there remain a lot of perceptual problems, strange bureaucratic procedures, unusual taxes, odd travel arrangements and peculiar customs. This is compensated by a strong native sense of humour, a natural anarchy and an ability to imbibe large quantities!

To satisfy the usual questions that customers ask, CST finds it very helpful to supply customers at an early stage with the latest edition of its 'Guide to Launching Small Satellites in the Countries of the Former Soviet Union', now in its 7th edition.